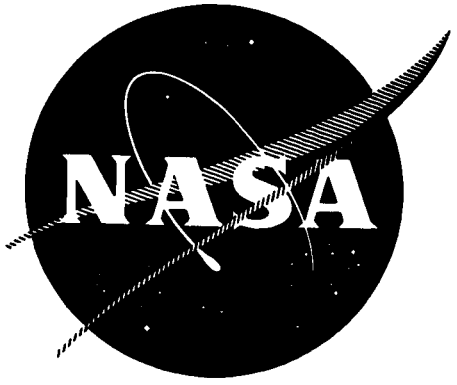

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EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
SONOTONE CORPORATION
20 AMPERE–HOUR
SEALED NICKEL–CADMIUM CELLS

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W11,252B

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

EVALUATION PROGRAM
FOR
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
SONOTONE CORPORATION
20 AMPERE-HOUR
SEALED NICKEL-CADMIUM CELLS

QE/C 67-562 28 August 1967

PREPARED UNDER THE DIRECTION OF

E. C. BRUESS
Manager, Electrochemical
Power Sources Branch

APPROVED BY

C. G. LYNCH
By direction

Enclosure (1)

REPORT BRIEF

SONOTONE 20 AMPERE-HOUR SEALED NICKEL-CADMIUM SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

I. TEST ASSIGNMENT BRIEF.

A. In compliance with references (a) and (b), evaluation of Sonotone 20 ampere-hour sealed secondary spacecraft cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. Fifty cells (25 control and 25 with springs) were purchased from Sonotone Corporation, Elmsford, New York, by National Aeronautics and Space Administration (NASA) under Contract NAS3-6001. The goal of this contract was to study the effect of mechanical pressure on cell plates of nickel-cadmium cells.

II. CONCLUSIONS.

A. From the results of this test, it can be concluded that:

1. The sealing technique used to secure the pressure relief values to the covers may be a problem area as evidenced by one leaker out of the 50 cells tested.

2. The mechanical pressure on the cell stacks makes no appreciable difference on initial capacities as the control cells had a capacity range of 23.8 to 29.2 ampere-hours as compared with the range of 24.8 to 30.0 ampere-hours for the cells with the springs.

III. RECOMMENDATIONS.

A. It is recommended that these Sonotone Corporation 20 ampere-hour cells be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS

OF

20.0 AMPERE-HOUR SEALED NICKEL-CADMIUM

SECONDARY SPACECRAFT CELLS

MANUFACTURED BY

SONOTONE CORPORATION

I. INTRODUCTION.

A. On 15 May 1967, this activity began acceptance tests on 50 cells. These tests were completed on 18 June 1967.

II. TEST CONDITIONS.

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Phenolphthalein Leak Test.
2. Capacity Test.
3. Cell Short Test.
4. Immersion Seal Test.
5. Overcharge Test.
6. Internal Resistance Test.
7. Immersion Seal Test.

B. All charging and discharging was done at constant current (±5 percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION.

A. The cells were identified by the manufacturers' serial numbers which were from C-1 to C-25 consecutively for the control cells and from S-1 to S-25 consecutively for the cells with the internal springs.

B. The 20.0 ampere-hour cells are rectangular in shape with average heights (base to top of positive terminal), lengths, widths and weights as follows:

Type	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
Control	5.423	1.425	3.159	1000.5
Springs	5.439	1.435	3.156	1074.1

The individual cell dimensions and weights are given in Table I. Figure 1 is a photograph showing the Sonotone Corporation 20 ampere-hour cell.

C. The 25 cells designated as control are of standard sealed nickel-cadmium construction. The 25 cells designated as springs have the standard construction plus a constant mechanical pressure (springs) normal to the face of the nickel-cadmium stack. This inovation is to determine if the constant mechanical pressure has any effect on the life of the battery.

IV. TEST PROCEDURE AND RESULTS.

A. Phenolphthalein Leak Test:

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed with a phenolphthalein spray indicator solution of one-half of one percent concentration.

2. There were no signs of leakage on any of the 50 cells subjected to the leak test.

B. Capacity Test:

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where C is the manufacturer's rated capacity, to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks were made at this activity. The cells were discharged individually, but were recharged in series.

2. Since complete capacity data was not submitted by the manufacturer, it was not possible to compare the manufacturer's results with those of this activity. The individual cell capacities ranged from 23.8 to 30.0 ampere-hours for an average of 26.4 ampere-hours to 1.00 volt. There was no appreciable difference between the capacities of the control cells and those with the springs. The cell capacities are tabulated in Table I. Characteristic 2-hour rate discharge curves are shown in Figures 2 and 3.

C. Cell Short Test:

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in insulating

materials or damage to the element in handling or assembly.

2. Following completion of the third capacity discharge test, each individual cell was loaded with a resistor of value giving a c/1 to c/5 discharge rate and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. No recovery value was used for the rejection of any cells.

3. The open circuit cell voltages, 24 hours after removal of the shorting resistors, ranged from 1.13 to 1.23 volts for an average of 1.19 volts. None of the 50 cells subjected to the short test were rejected.

D. Immersion Seal Test:

1. The immersion seal test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence and cause of leaks.

2. The cells were placed under water in a bell jar container. A vacuum of 20 inches of mercury was held for 3 minutes. Cells discharging a steady stream of bubbles were considered rejects.

3. One cell was found to leak between the cover and the pressure relief valve during the test performed after the overcharge test sequence. Mr. William Nagle of National Aeronautics and Space Administration, Lewis Research Center, was notified. He decided to leave the cell in the program to gather all information possible on the cell.

E. Overcharge Test:

1. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at the c/20 rate for 48 hours and at the c/10 rate for 16 hours. The c/5 rate was not used because of the problem of cell pressure damaging the restrained cells.

2. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts while on charge. There was no need to remove any cells from the charging sequence.

3. The steady state voltage at the end of each charging sequence is shown in Table I. Characteristic overcharge voltage curves are shown in Figures 4 and 5.

F. Internal Resistance Test:

1. This test was performed to determine the internal resistance of the cell.

2. At the completion of the overcharge test, the cells were returned to the c/20 charging rate and given a short pulse (5-10 seconds) at the rate of C in amperes. The cell voltages, V1, immediately prior to the pulse; and V2, 5 milliseconds after the pulse, were read on a suitable recording instrument. A CEC high speed recorder (28.8 inches of tape per second) was used. The internal resistance of the cell in ohms was calculated according to the following formula.

$$R = \frac{V2 - V1}{Ic - Ic/20}$$

V1 and V2 are in volts, Ic and Ic/20 are in amperes.

3. The internal resistance value for each cell is shown in Table I. The values range from 0.53 to 4.21 milliohms.

TABLE I

CELL NUMBER	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CELL SHORT TEST (VOLTS)	IMMERSION SEAL TEST	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST
CONTROL CELLS													
1	5.440	1.436	3.169	1008.0	23.5	24.3	23.7	1.17	O.K.	1.42	1.46	1.05	O.K.
2	5.435	1.430	3.144	1005.9	25.3	25.0	24.3	1.20	O.K.	1.42	1.43	0.53	O.K.
3	5.420	1.423	3.160	997.7	25.5	28.0	27.7	1.18	O.K.	1.45	1.47	0.53	O.K.
4	5.444	1.425	3.160	996.4	25.5	26.7	26.0	1.16	O.K.	1.43	1.46	1.05	O.K.
5	5.450	1.420	3.168	1003.9	23.7	24.7	24.3	1.19	O.K.	1.43	1.46	1.58	O.K.
6	5.435	1.425	3.142	1005.7	24.0	25.0	25.5	1.18	O.K.	1.43	1.46	0.53	O.K.
7	5.460	1.440	3.168	1002.5	23.8	23.8	23.5	1.16	O.K.	1.42	1.44	0.53	O.K.
8	5.450	1.422	3.156	998.3	23.8	24.3	23.8	1.18	O.K.	1.43	1.46	0.53	O.K.
9	5.431	1.418	3.150	1010.3	24.2	24.8	24.5	1.19	O.K.	1.43	1.46	0.53	O.K.
10	5.450	1.425	3.158	1000.6	24.3	25.3	25.0	1.19	O.K.	1.44	1.47	0.53	O.K.
11	5.415	1.428	3.144	995.8	22.5	24.3	23.5	1.18	O.K.	1.41	1.43	0.53	O.K.
12	5.410	1.421	3.150	987.2	23.0	23.3	24.7	1.19	O.K.	1.43	1.50	0.53	LEAKED
13	5.432	1.425	3.132	1002.8	25.0	24.8	23.5	1.22	O.K.	1.42	1.42	0.53	O.K.
14	5.455	1.434	3.155	1009.8	24.7	25.0	24.3	1.22	O.K.	1.42	1.44	1.05	O.K.
15	5.436	1.420	3.150	989.6	25.1	24.7	23.7	1.20	O.K.	1.42	1.43	1.05	O.K.
16	5.440	1.425	3.160	1001.0	25.1	26.7	26.0	1.18	O.K.	1.44	1.46	3.68	O.K.

TABLE I (contd)

CELL NUMBER	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CELL SHORT TEST (VOLTS)	IMMERSION SEAL TEST	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST
						CONTROL CELLS							
17	5.449	1.425	3.150	1010.8	25.0	25.0	24.7	1.17	O.K.	1.42	1.45	0.53	O.K.
18	5.436	1.421	3.130	986.2	25.3	25.0	24.0	1.20	O.K.	1.42	1.43	0.53	O.K.
19	5.456	1.425	3.163	1002.0	24.8	25.3	24.7	1.17	O.K.	1.43	1.46	1.05	O.K.
20	5.433	1.414	3.168	1003.2	25.1	25.0	24.7	1.18	O.K.	1.43	1.47	1.58	O.K.
21	5.450	1.413	3.200	997.1	26.3	29.2	27.3	1.19	O.K.	1.41	1.45	2.63	O.K.
22	5.510	1.440	3.200	990.7	25.7	25.2	24.3	1.20	O.K.	1.41	1.45	0.53	O.K.
23	5.434	1.420	3.175	1002.7	25.2	24.6	23.7	1.22	O.K.	1.39	1.44	0.53	O.K.
24	5.450	1.420	3.169	1006.4	25.7	26.5	25.8	1.21	O.K.	1.40	1.44	0.53	O.K.
25	5.450	1.421	3.163	998.2	25.5	26.0	25.3	1.22	O.K.	1.39	1.41	2.63	O.K.
						SPRING CELLS							
1	5.400	1.421	3.155	1083.0	25.2	28.5	22.5	1.21	O.K.	1.40	1.42	3.68	O.K.
2	5.440	1.441	3.156	1070.3	24.8	27.8	23.0	1.19	O.K.	1.41	1.45	0.53	O.K.
3	5.444	1.420	3.155	1067.2	24.8	26.8	20.5	1.19	O.K.	1.41	1.42	0.53	O.K.
4	5.436	1.477	3.175	1074.3	25.3	27.8	22.6	1.17	O.K.	1.45	1.47	0.53	O.K.
5	5.459	1.425	3.160	1070.2	24.8	27.0	19.7	1.20	O.K.	1.40	1.42	4.21	O.K.
6	5.430	1.429	3.144	1074.5	24.6	28.2	20.6	1.18	O.K.	1.41	1.47	0.53	O.K.
7	5.450	1.421	3.145	1069.2	24.8	26.8	19.8	1.17	O.K.	1.40	1.42	1.05	O.K.

TABLE I (contd)

CELL NUMBER	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CELL SHORT TEST (VOLTS)	IMMERSION SEAL TEST	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST
						SPRING CELLS							
8	5.437	1.450	3.150	1070.3	25.7	27.5	21.3	1.13	O.K.	1.42	1.47	0.53	O.K.
9	5.445	1.419	3.157	1081.7	25.8	27.8	25.3	1.18	O.K.	1.41	1.43	1.05	O.K.
10	5.436	1.425	3.150	1080.7	25.3	28.0	24.0	1.20	O.K.	1.40	1.44	1.05	O.K.
11	5.428	1.416	2.132	1059.0	24.2	24.8	24.0	1.22	O.K.	1.40	1.42	0.53	O.K.
12	5.448	1.434	3.160	1073.4	24.5	26.8	26.8	1.20	O.K.	1.41	1.46	0.53	O.K.
13	5.429	1.440	3.155	1075.1	24.2	25.8	25.8	1.22	O.K.	1.40	1.45	0.53	O.K.
14	5.465	1.457	3.150	1072.3	25.2	26.8	26.6	1.19	O.K.	1.44	1.46	0.53	O.K.
15	5.436	1.430	3.161	1075.8	26.0	27.0	26.3	1.20	O.K.	1.41	1.45	0.53	O.K.
16	5.450	1.480	3.164	1069.2	26.2	28.2	20.0	1.17	O.K.	1.44	1.46	0.53	O.K.
17	5.455	1.421	3.160	1074.0	25.2	27.2	26.0	1.21	O.K.	1.40	1.45	0.53	O.K.
18	5.423	1.425	3.144	1082.6	24.7	27.2	26.2	1.22	O.K.	1.39	1.41	0.53	O.K.
19	5.425	1.445	3.165	1072.0	23.7	27.2	26.0	1.21	O.K.	1.41	1.45	0.53	O.K.
20	5.435	1.416	3.160	1067.9	22.5	26.5	24.5	1.22	O.K.	1.39	1.41	0.53	O.K.
21	5.430	1.430	3.168	1069.5	22.3	26.5	23.3	1.23	O.K.	1.40	1.44	0.53	O.K.
22	5.453	1.440	3.140	1088.9	22.8	27.7	25.7	1.20	O.K.	1.41	1.45	0.53	O.K.
23	5.440	1.440	3.190	1083.0	22.0	27.0	25.0	1.21	O.K.	1.40	1.42	0.53	O.K.

TABLE I (contd)

CELL NUMBER	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CAPACITY TEST (a.h.)	CELL SHORT TEST (VOLTS)	IMMERSION SEAL TEST	OVERCHARGE c/20 (VOLTS)	OVERCHARGE c/10 (VOLTS)	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST
						SPRING CELLS							
24	5.444	1.444	3.155	1074.0	23.0	26.2	24.0	1.20	O.K.	1.42	1.46	0.53	O.K.
25	5.428	1.435	3.156	1074.0	26.2	28.3	26.2	1.16	O.K.	1.43	1.47	3.16	O.K.

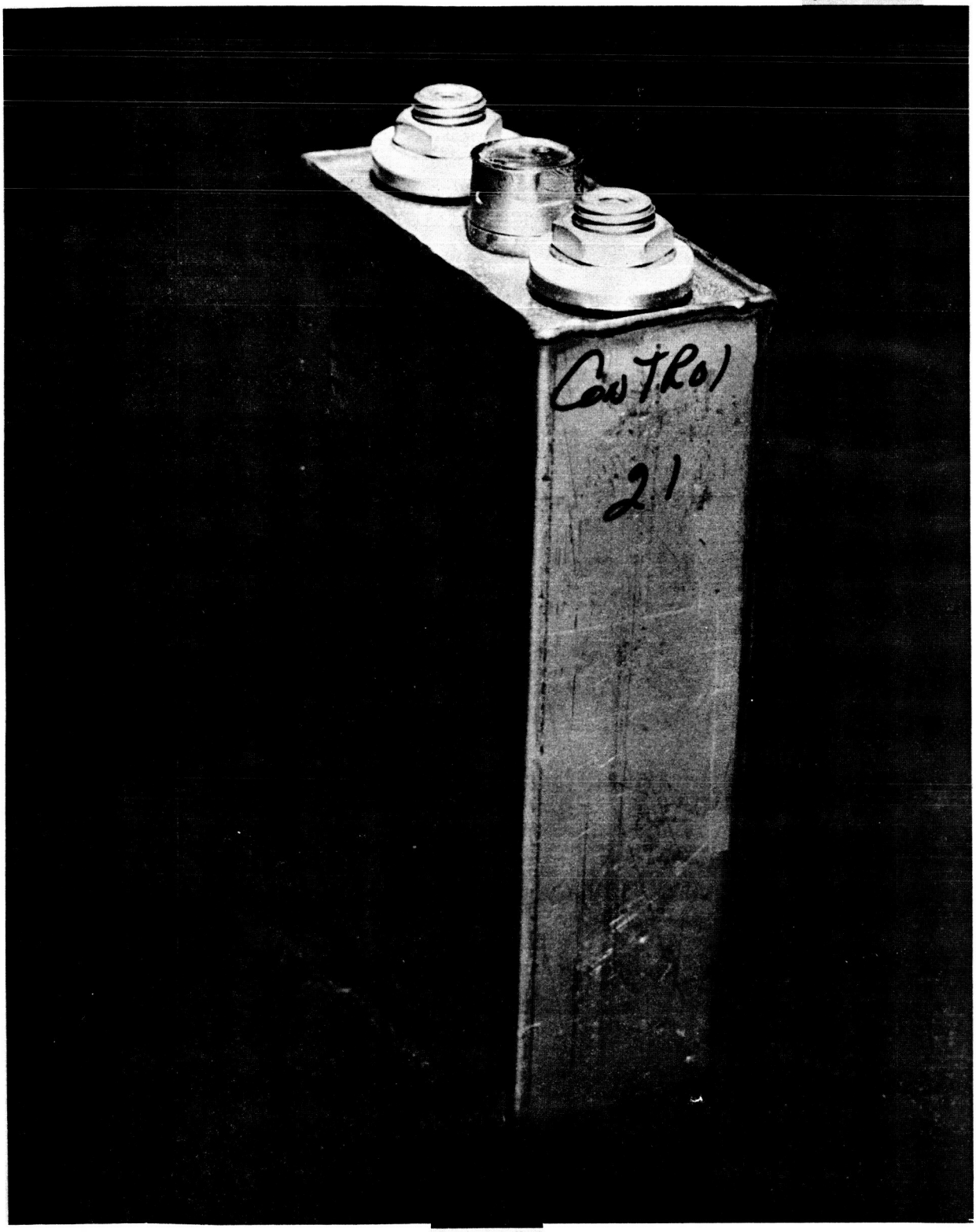
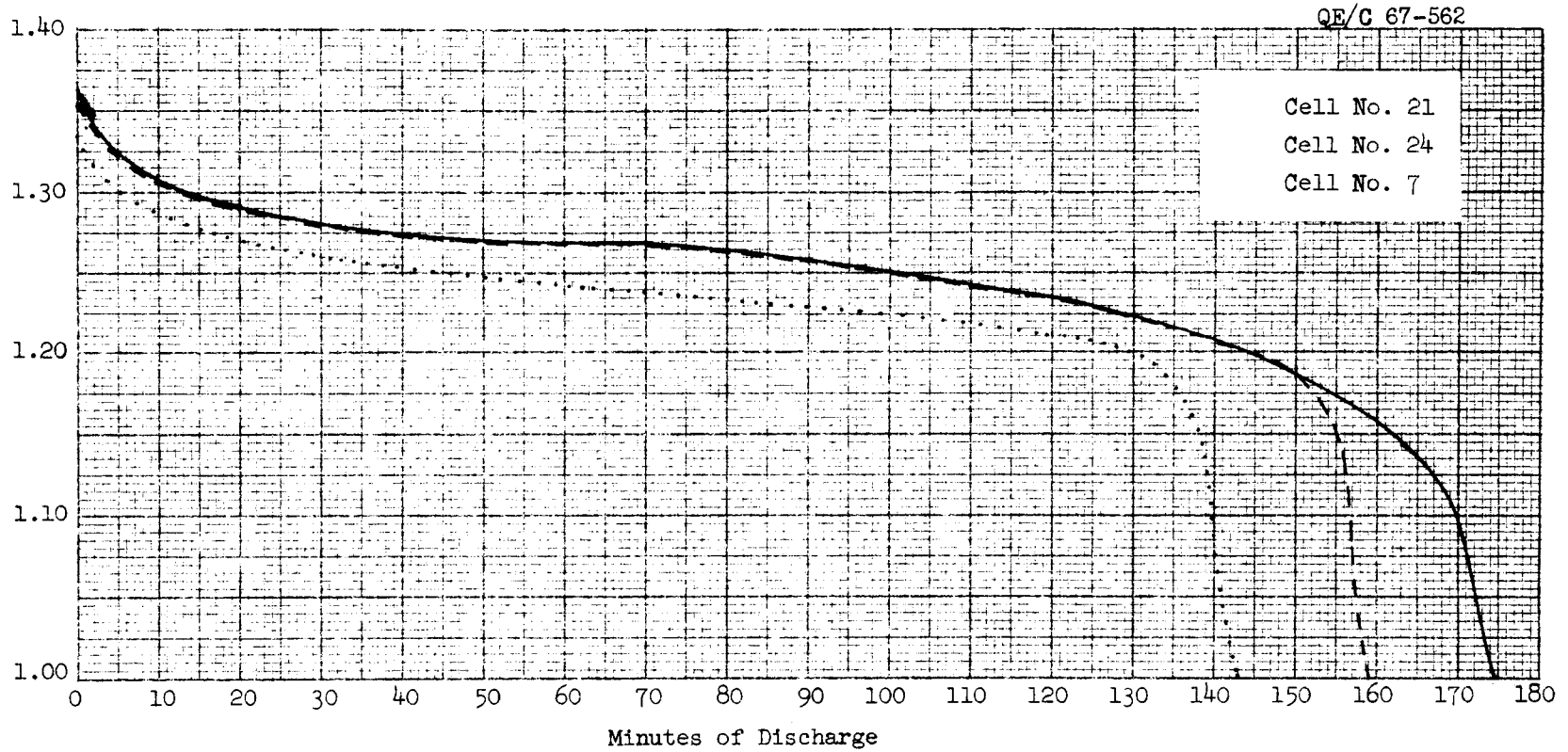


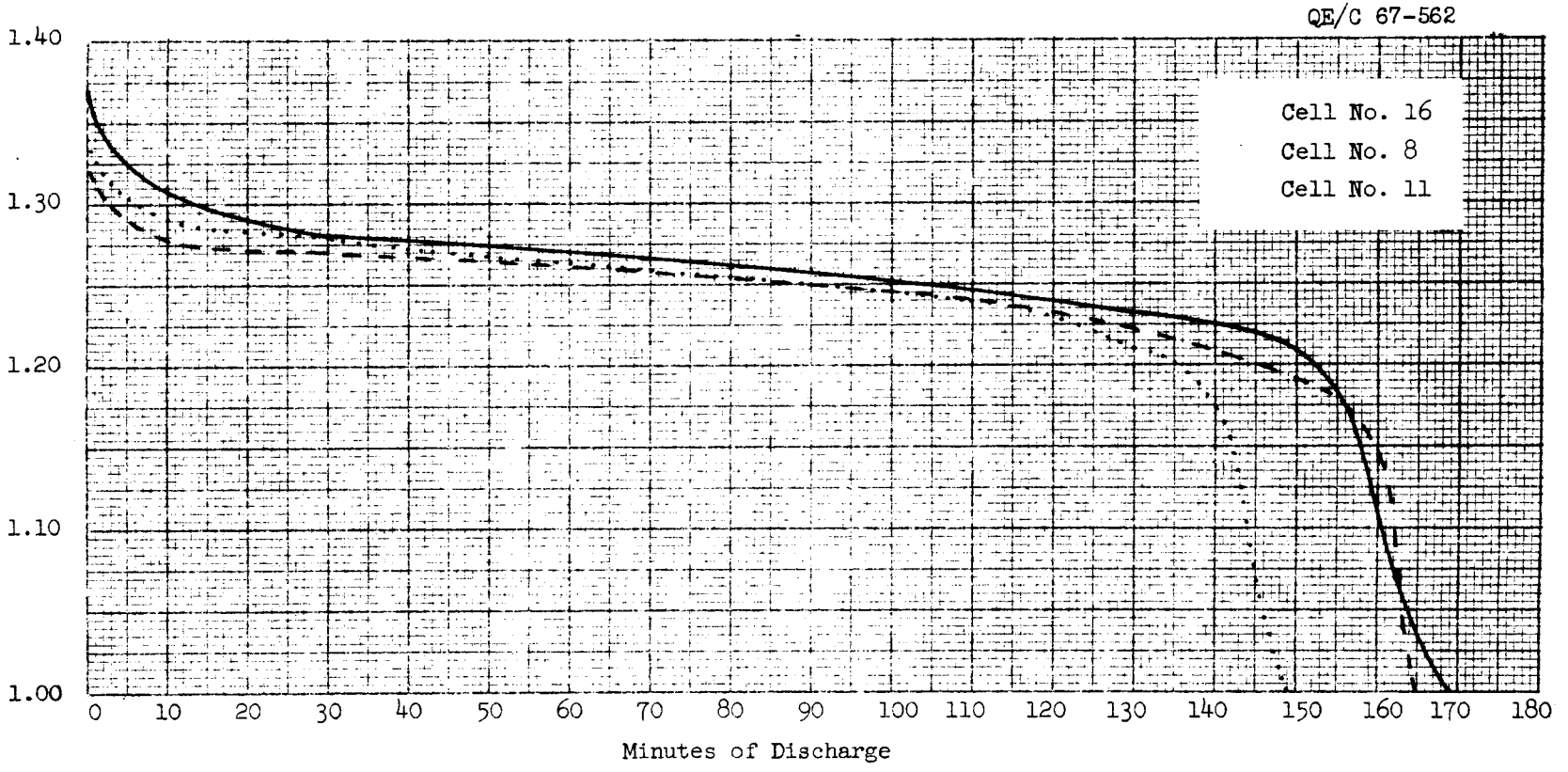
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE

SONOTONE 20 AMPERE-HOUR NICKEL-CADMIUM SEALED CELLS (CONTROL)

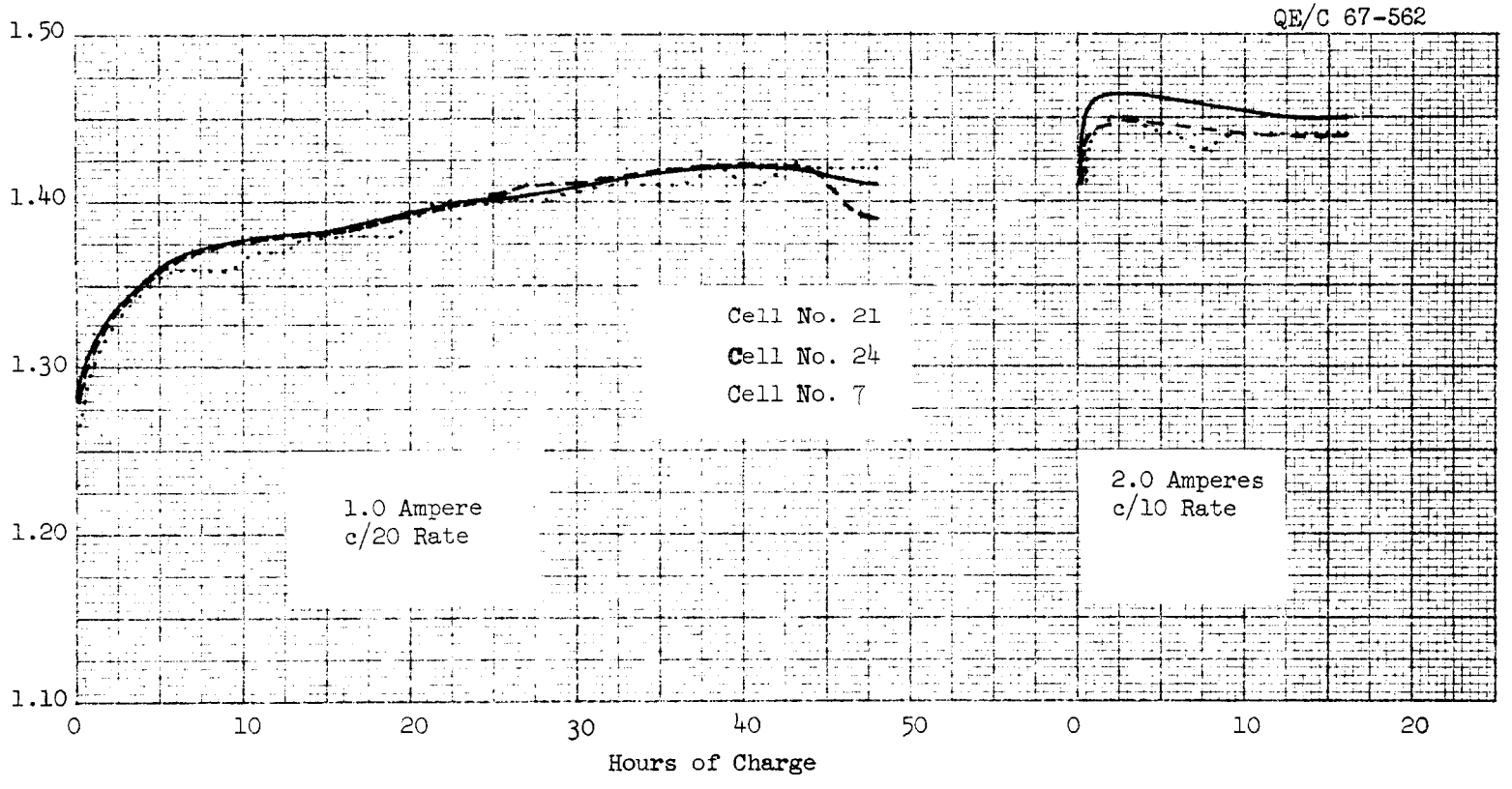
FIGURE 2



CHARACTERISTIC 2-HOUR RATE DISCHARGE

SONOTONE 20 AMPERE-HOUR NICKEL-CADMIUM SEALED CELLS (SPRINGS)

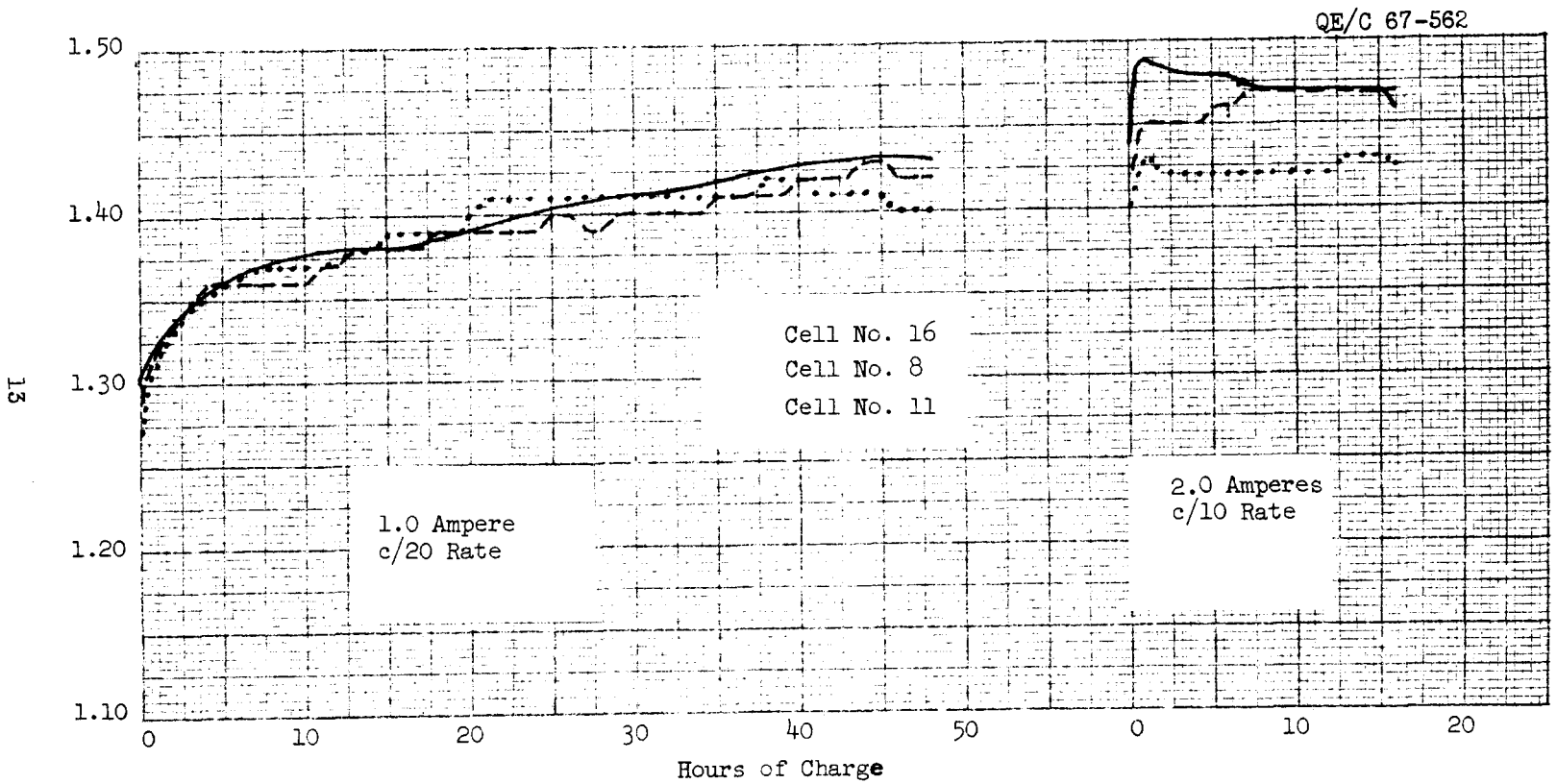
FIGURE 3



CHARACTERISTIC OVERCHARGE CURVES

SONOTONE 20 AMPERE-HOUR NICKEL-CADMIUM SEALED CELLS (CONTROL)

FIGURE 4



CHARACTERISTIC OVERCHARGE CURVES

SONOTONE 20 AMPERE-HOUR NICKEL-CADMIUM SEALED CELLS (SPRINGS)

FIGURE 5

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40 National Aeronautics and Space Administration, Office of Technology Utilization, Washington, D. C. 20546

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